HANGING VALLEYS OF THE YOSEMITE

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Yosemite Valley, 1
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W. P. Blake (1900)
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result of glacial deepe
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The following page
River in the Yosemite
tributary streams; the
Merced, by which the
cess of valley widening
present width of the
of the hanging valley
and their relation to
the

THE FORMER

In an earlier number
set forth in some detail
tributary hanging valleys
with reasonable accurac
main valley has suffered
discussion of the limitati
measurements of gradient
festly should not be based
courses of tributaries, the
streams having highly irre
streams. If measurement
tributaries several miles in
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main stream may be asce
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The Valley Map
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Valley Map. The g
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Snow Creek, as show
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Illilouette Creek prese
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In concluding his
Turner mentions four
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1. That it was h
2. That it was coop
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3. That it was ction
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4. That it was l).
jointing (Becker s forme
Branner,

To the objections urged
the above theories (faulting)
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and Tenaya Creek before t
formed; the relation of trib
changed by the formation of t
their hanging character; hence
the down-faulted block must
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Ierced River; and
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canyon cutting farther down the slope seems unnece
incompatible with the widespread evidence of gla
stead of protection, in the glaciated areas.

Consequent upon the uplifting and tilting of the
leveled surface, the Merced and other large sou
streams must have entrenched themselves very rapidl
tributaries deepened their valleys more gradually, es
flowed at right angles to the main stream and henc
their gradients affected by the southwest tilting. Th
valleys would come to hang above the main stream.
ment of the hanging relation was presumably most pr
the middle courses of the Sierran rivers; for near th
hills the amount of uplift is so slight that no great
junction of main and tributary streams is possible;
headwater areas the contrast in volume between the m
a tributary decreases to such an extent that one is al
ful as the other. Even if tilting increased the gradie
stream alone, in the headwater areas, there could har
great a discordance in junction as would occur fart
valley where the main stream not only experienced the
in gradient, but was also a much more powerful st
tributaries.

There is a distinct limit to the time during which ha
can remain as such. As soon as a main stream has e
trenched itself, and begins to establish a profile of gentl
energy decreases. The tributary streams continue to
valleys until accordant junctions with the main strea
lished. It is a well-substantiated law of stream action
required for a main stream to reduce its channel to a f
and to open out its valley floor to a width not many t
than the width of the stream, is longer than the time
hanging tributaries to reduce their valleys to accorda
Accordingly, while hanging valleys might exist along
and similar rivers, especially along the middle courses of
so long as the main streams occupied narrow V-shape
fairly steep gradient, it is safe to say that the more open
main valley floor became, the less would the tributary v
and that where the main valley floor had come to be s
wider than the stream, and of very low gradient, no han
would exist.

If we proceed on the assumption that the glaciers wh
the upper portions of some of the Sierra canyons we

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Sierra region
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along its

course which would intersect the North Fork, to w
tributary, something less than 400′ above the pres
Fork. It is apparent that these hanging valleys, wh
not typical, and whose discordance in junction is us
hundred feet, are not to be compared with the hangi
Yosemite, where tributary streams cascade abruptly

Fig. 2—Yosemite Valley looking east.

valley walls, and have a quite uniform discordance in
more than two thousand feet.

The hanging valleys west of El Portal enter a narr
gorge of fairly pronounced gradient. The hanging va
Yosemite enter a main valley (Figure 2), whose floor is
the width of the main stream, and whose gradient is un

wide open valleys, such as the Yosemite, which appear to afford strong evidence in favor of glacial erosion.

Instead of disproving the glacial origin of the Yosemite, the comparison of valleys suggested by Turner really affords strong evidence in favor of the theory of glacial erosion. It is no mere coincidence that of the six valleys named by that writer the two most unlike the Yosemite have presumably suffered little or no glaciation, whereas the four most like the Yosemite served as the outlets of extensive glacial basins. The areas of these basins may be determined roughly by drawing boundaries which shall enclose all of the strongly glaciated region tributary to the several valleys. Although this does not take account of the passage of ice from one basin to another across the present divides, the method is sufficiently accurate, when applied to alpine regions of strong relief, to enable one to discriminate between profoundly and slightly glaciated basins, and between basins which favor extensive erosion of the master valley, and those which do not.

The valley near Sugar Loaf, on the South Fork of the American River, is so little like the Yosemite that the contour map leaves one in doubt as to why they should be compared; for the contours represent a V-shaped gorge without hanging valleys, although a few of the tributaries have their lower courses somewhat over-steepened. The basis of comparison with Sawmill Canyon is simply that the latter "under favorable circumstances would widen out into a Yosemite"; but since this questionable statement involves the very point at issue, the comparison is not permissible. On the other hand, the small valley on the Middle Fork of Stanislaus River at the mouth of Niagara Creek bears some resemblance to the Yosemite by reason of its steep walls and flat floor; but the contour map shows such marked evidences of glaciation in the headwater portions of streams draining into this valley that it seems quite probable that a glacier traversed the valley and gave to it its peculiar form. The area of the glacial basin is smaller in this case than in the others mentioned below, and this may account for the small size of the glacial trough on the Middle Stanislaus. Hetch Hetchy Valley is truly another Yosemite, larger than the valley on the Middle Stanislaus, because it is the outlet of a larger and more profoundly glaciated basin. It is smaller than the real Yosemite, because its glacial basin, while very large, is very asymmetrical (Fig. 3 a). The ice streams, instead of flowing comparatively short distances to the center of the basin and there uniting to form a large and powerful glacier, as in

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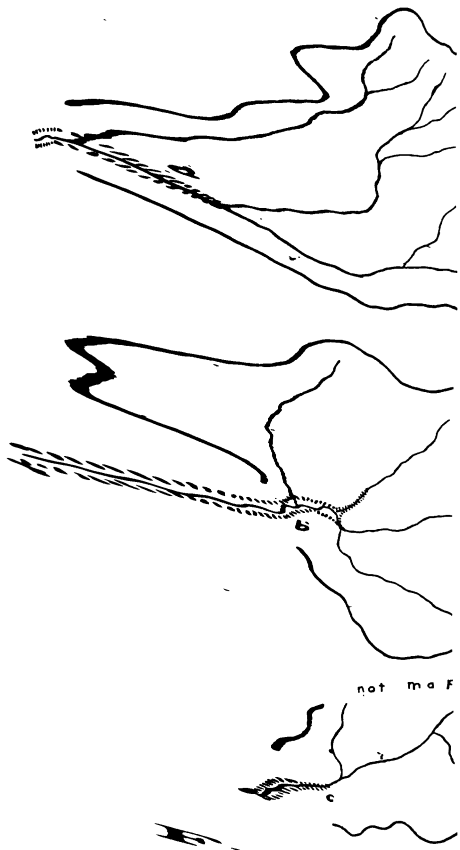

FIG. 3—Sketch maps
drainage basins.
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Yosemite basin
the Hetch Het
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which glaciatio

trough form is marked, this valley is less striking than the Yosem presumably because its glaciated basin is less symmetrical and p mitted less concentration of the ice streams than was the case w its more fortunate neighbor. The Grand Canyon of Kings Riv the last of the valleys mentioned by Turner, is the outlet o splendid glacial basin (Fig. 3 e); consequently it is itself a splen glacial trough. One might add to the above list Kern Canyon, wh has the trough form well developed, because it is the outlet o basin (Fig. 3 d) in which glaciation was profound, and is so sha as to admit of a fair concentration of ice streams. Yosemite Va owes its preëminence to the favorable combination of several ments: (1) a remarkably symmetrical basin, which was (2) p foundly glaciated, and which permitted (3) intense concentration ice streams, one of which was augmented by (4) overflow ice fr a neighboring basin. Variations in the country rock doubtless play their part in giving to the different troughs different degrees of p fection; but I regard rock differences as of less importance th differences in the size, shape, and extent of glaciation, of the ba for which the troughs serve as outlets.

Turner has suggested (p. 318) that the Yosemite Valley may ha acquired a depth of 1,000 feet by the beginning of the Pleistoce and that this "lessens the difficulty of accounting for the prese depth of the Yosemite and of other canyons of the southern Sierr The elevation of the Merced River previous to glacial overdeepeni was, as shown above, from 2,000 to 2,500 feet above the prese level of the stream, or between 6,000 and 6,500 above present level. This may have been 1,000 feet below the higher parts of imperfectly developed peneplain. In any case, the present hang valleys appear to have been graded with reference to that elevati of the Merced, and the indications are that the Merced at that ti occupied an open valley as did the tributaries. The difficulty wh confronts the theory of stream erosion of the Yosemite is not absolute depth of the canyon, but rather the relation of the broa floored main valley to the hanging valleys. This difficulty is lessened by imagining an earlier or later date for the initation canyon cutting.

The character of Tenaya Canyon has always been a serious di culty in interpreting the Yosemite as a stream carved valley. Tena Creek, with a drainage area little if any larger than that of Yosem Creek, flows through a wide open valley to an accordant junct with the aggraded floor of the open Yosemite Valley, instead dropping 2,000 feet or more from a hanging valley. Assuming n

mal stream erosion, it is hard to see why c
be able to reduce its valley to grade and t
to a considerable width, while a similar tr
but a small beginning on so vast a work.
has suggested that the Lyell Fork of the T
were formerly headwaters of Tenaya Creel
by the Tuolumne River. This would acco
volume of Tenaya Creek, under which con
canyon would seem less remarkable. Tur
this possibility, but on the evidence of rive
"very improbable." Even if we suppose th
age formerly came through Tenaya Canyon
culties in explaining the relation of the canyo
On the other hand, if we accept the very re
during the glacial period much ice from the T
the low divide into the Tenaya Basin, and
(305-306) and Gannett (87) that the Tenaya
ice stream which entered the Yosemite V
theory of glacial erosion, an adequate explana
observed. The Tenaya Canyon owes its U-sl
its depth below the hanging valleys to glacia
is deeper and more imposing than other v
Yosemite, because it was carved by the m
glacier. The small Tenaya Creek is even m
spending portions of the main Merced River
valley, because the Tenaya Glacier was larg
than the Little Yosemite Glacier.

THE LONGITUDINAL PROFILE OF THE

Reference has been made above to the f
streams entering the Merced west of El Po
Bear Creek and the North Fork of the Merced
lower courses. They join the Merced with acc
a short distance back from the main river show
ient, while their upper courses are again of gent
not be surprised to find a comparable feature in
farther up stream. For while an even tilting w
the gradient of the main river uniformly th
greater volume would allow the lower course to
rapidly. If to difference in volume we add diffe
ance, it is easy to see how one part of the strea

rock might intrench itself more rapidly than a part up stream on more resistant rock, thus developing a locally steep gradient which would gradually retreat up stream. Something of this nature is shown in the longitudinal profile above (east of) El Portal. It should be remembered that, west of El Portal, the valley of the Merced is unglaciated, while east of the western end of the Yosemite, the valley has been profoundly glaciated. Between these two points, El Portal and the western end of the Yosemite, the valley has been traversed by glaciers to some extent, and shows the effects of glacial erosion very distinctly near the Yosemite, but to a decreasing extent toward El Portal. Had the pre-glacial Merced possessed a well-graded profile in this region, we should expect to find now, as a consequence of glacial erosion, a gradual decrease in gradient above El Portal, until the gradient finally became approximately flat, or even reversed, in the Yosemite Valley, where glaciation was most profound. Instead, we find a very pronounced steepening of the gradient above El Portal, similar to the steepening observed in the lower courses of the non-glaciated tributary streams farther west. It is evident that before glaciation the main river had not completely graded its course, although it had pushed the over-steepened zone as far up stream as El Portal. From this point the profile rose rapidly to a level some 2,000 feet above the main portion of the Yosemite Valley, as shown by the position of the hanging valleys. The western part of the Merced was then entrenched, the eastern part still flowing on the uplands. Glacial erosion has greatly altered the profile of the eastern part, but some trace of the pre-glacial conditions persists in the over-steepened profile east of El Portal.

Valley Widening in Jointed Rocks

One of the most evident relations in the present topography of the Yosemite Valley is the control of joint planes upon weathering and erosion. Impressed by the remarkable form of the Yosemite Valley as a whole and by the important influence of jointing upon the form of the valley walls, some observers have genetically connected the two, seeking to explain the former by the latter. Unfortunately, no one who supports this view has set forth in detail just how stream erosion on jointed rocks can develop valleys essentially different from those developed by stream erosion on unjointed rocks. A brief analysis of this phase of the Yosemite problem may not be amiss. Let us first consider the process of valley development in massive, unjointed rocks.

If a main stream incises itself with suc
weather back but slightly before a deep tre
come to flow in a narrow chasm with mo
walls. The width of such a chasm is littl
width of the stream. Tributaries may en
slowly, and so give rise to lateral hanging
weathering to proceed more rapidly, the wa
treat as the stream cuts downward. Two
the higher portions of the walls retreat fart
tions. First, the higher portions are expose
weather for a longer time. Second, a greate
rock is in unstable equilibrium near the top
near the bottom. Just at the stream level n
position, and weathering must proceed ver
has little or no chance to remove the rock fra
widening due to weathering is at a minimum a
above the stream level a narrow segment of ro
to fall down into the stream as fast as its
weathering. Here the valley may be widened s
ing alone. The corresponding segment of r
weather from still higher levels is much greate
valley may weather to a width of a mile or m
remains the width of the stream itself.

The above is perhaps an over elaborate s
recognized relation between stream incision a
results in the V-shaped cross-profile of most y
It should not be inferred that the young str
cutting while entrenching itself, for lateral ero
weathering in producing the width of the vall
youth of a stream, when down-cutting is active,
cutting is ordinarily obscured by the far greater
It is fair to say that during youth, valley deepeni
stream cutting, valley widening largely due to
it follows that a young stream cannot develop
floor. Beginning with maturity, valley deepenin
importance, and valley widening may be due mo
than to weathering. A flat valley floor, many tim
stream, may be developed.

Let us now consider whether the above princip
case the valley walls are intersected by joint pla
joint planes may produce the greatest effect upon
must be neither too widely nor too closely spac

we imagine
valley will re-
erate to make
the lower por-
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se breadth of
w chasm than
in an unstable
where gravity
Hence, valley
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too widely

rock, such as granite, ... of such frequency as to make the inclu... not excessive size. The process of weat... tated by the jointing; but it does not a... produce any essential modification o... planes sloping toward the stream will a... to remove the granite blocks which are... quickly than would weathering in unjo... shaped cross-profile will be the more qu... joint blocks at stream level are in a stab... normal weathering is known which wo... a place against the pull of gravity, in ... the V. They cannot be washed away b... massive or broken by joint planes, the ... must wear away little by little, even t... fall from unstable positions high up on... true, no matter what varieties of jo... Vertical joints will leave temporary, v... block falls from place. A vertical fa... must slowly weather back to a mor... quickly incises itself in vertically joint... row chasm with vertical walls. But ... its effects apparent, we must have a ... top of the gorge than at the bottom, t... long as the stream is youthful.

Returning to the case of the Yos... undoubted characteristic of youth in ... width of the main valley cannot be la... the valley floor is broad and flat. Join... tate weathering, are present in the v... influencing the weathering now in proc... ing in jointed rocks can account for the... The hanging valleys confirm the con... Yosemite is not due to weathering; fo... valley wall are worn back, by erosion ... faster rate than are the interstream a... active. If the walls of the Yosemite h...

tributary streams, and especially the
far back from the main valley as to h
effect. Instead, we find the tributar
ley walls, or descending in slight
breaking away of joint blocks whi
the steep valley walls.

One can conceive that valley
lateral cutting by a shifting stre
a flat-floored, steep-walled valley
to a comparatively negligible
mately one level will widen
valley walls. Granted the fav
ing stream eroding laterally w
slowly in comparison with t
traversed by vertical planes c
of the valley walls to take p
faces on the retreating cliffs

That the broad floor an
not have this origin is e
valleys. The latter wou
Merced River could have
ing of its course and the

The existence on the sa
of young streams, and
streams, demands a sp

There is a special
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very weak rock, betv
permits rapid entre
valley floor in the
hard rock, advance
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erosion, even w
rock exist. Th
resistance exist
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the width ar
quickly rem

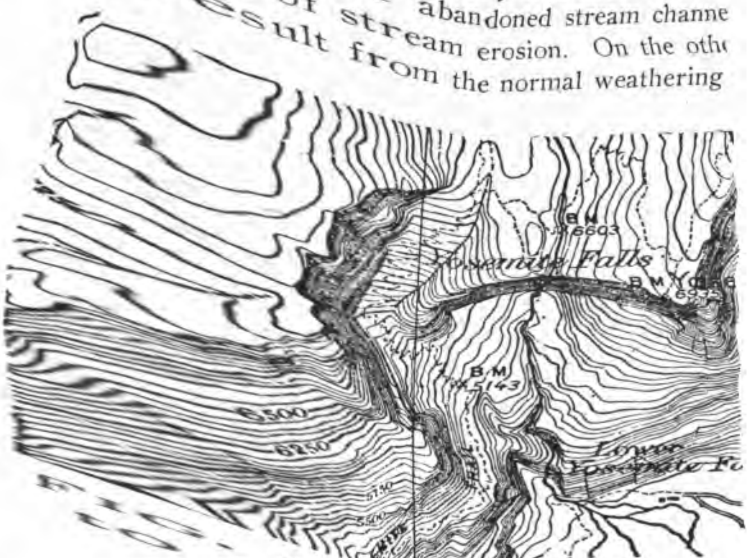
the present walls. A far more reasonable hypothesis is to regard the Yosemite Valley as one of the many open main valleys with hanging tributaries which characterize every region of Alpine glaciation, and which are reasonably interpreted as the product of glacial over-deepening of pre-existing river valleys.

It may be pointed out that the remarkable effects of jointing observed in the walls of the Yosemite are indirectly due to glacial over-deepening and over-steepening. Not until glacial erosion had made the steep-sided trough, was full opportunity given for the joint blocks to fall from place leaving the angular re-entrants and vertical faces which form such an important element in Yosemite scenery. Weathering and gravity have worked to great advantage in the recent past, and the resultant features are bold and striking. In the future, as the walls wear back to more gentle slopes and the more stable position of the joint blocks causes them to waste gradually away instead of falling in large masses from the cliffs, the valley walls will become cloaked with debris, the bold features of today will give place to more flowing, graded profiles, and the grandeur of Cathedral Rocks, Three Brothers and Half Dome will be a thing of the past. The influence of jointing on weathering is thus to be interpreted as an indirect effect of the glacial origin of the valley, rather than as an important agent in the formation of the valley.

The Notches Beside the Falls

As an observer stands in the Yosemite Valley and views the cataract of the Yosemite, Lower Yosemite, Illilouette, Vernal or Nevada Falls, he notes that beside each fall is a deep notch which the stream curiously avoids, to fall over a sheer cliff, as if to provide for man the most stupendous spectacle possible. Branner has given us a good description of this peculiar topographic feature (547-553), and has attributed the formation of the notches to the action of the several streams during a time when they were displaced from their normal positions by ice. A glacier occupied the bottom of each valley, forcing the stream to take a course some distance to one side, where it was held between the ice and the valley wall. While in this position the notch was cut. When the glacier disappeared the stream returned to its former position, leaving the notch deserted. Inasmuch as the stream cut the notch back faster than the glacier eroded its channel, it was argued that glaciers must have very little eroding power, and that the Yosemite Valley must therefore be the result of normal stream erosion in jointed rocks.

The present visitor to the Yosemite m
lent topographic map, which was not av
his account of the notches. An inspect
necessity of some modification of this
the field evidence confirms the sugg
Lower Yosemite Falls, Illilouette Fall
up at a higher level in the floors of th
cut, as required by Branner's theory.
no signs of abandoned stream channe
signs of stream erosion. On the oth
to result from the normal weathering



4—Yosemite Falls. Showing abandoned st
the west, through which the trail passes. V
Yosemite Falls is a notch due to weathering al

valleys would leave oblique scar
intersected the axes of the valle
scarp meeting the valley wall on
such a notch as we find at each
notches at Vernal Falls (Fig. 6)
are developed on NW-SE joints
joint which gives form to the sc
Liberty Cap. The notch at Ill
NE-SW joint plane, similar in
Nevada Falls and on the steep f
The notch at Nevada Falls (F
notch, but it does not open on
sented in Branner's sketch map

Falls do open
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otches are no
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along oblique
planes. When
member that
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sy to realize
the granite
break down
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ve blocks
from the
hanging
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An oblique
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ls (Fig. 4)
stem as the
derick and
s due to a
appear at

am carved
as repre-
rely in the

glacial displacement to get the stream in
stream flows naturally into it even now.
that the notch was cut in the bottom of th
ditions, and that a slight displacement,
turned the stream into its present course

The notch beside the Upper Yosemite Falls is similar in origin to that beside the Nevada Falls. Yosemite Creek formerly flowed through the notch, but was shifted to its present position, doubtless by a late advance of the Yosemite Creek Glacier. It would seem that Yosemite Creek acquired its abnormal position earlier than did the Merced River at Nevada Falls, since the creek has had time to entrench itself to a noticeable extent, alt
course of the creek may still be observed
notch which is followed by the trail for s

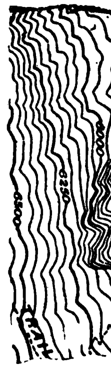

FIG. 5—Ill
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The existence of two distinct types
in the Yosemite region is clearly show
which the above figures are reproduced.
tion of their dual character came from a
this paper had been prepared for presenta
ings in Boston during the last convoca
Matthes recognized the dual character of
work.

Returning to the question as to what
concerning the relative efficiency of stre
should be noted that the notches at Lowe
Falls and Vernal Falls afford no evidence
were formed independently of stream
Upper Yosemite Falls and Nevada Fal
erosion after the main valley had been ov

ice advance which displaced the strea
According to the theory of glacial ero
deepened by ice action. Hence the no
younger than (part of) the glacial dee
older than the glacial displacement of
courses. the
Post-glacial cutting has formed on
streams now pass over the ledges

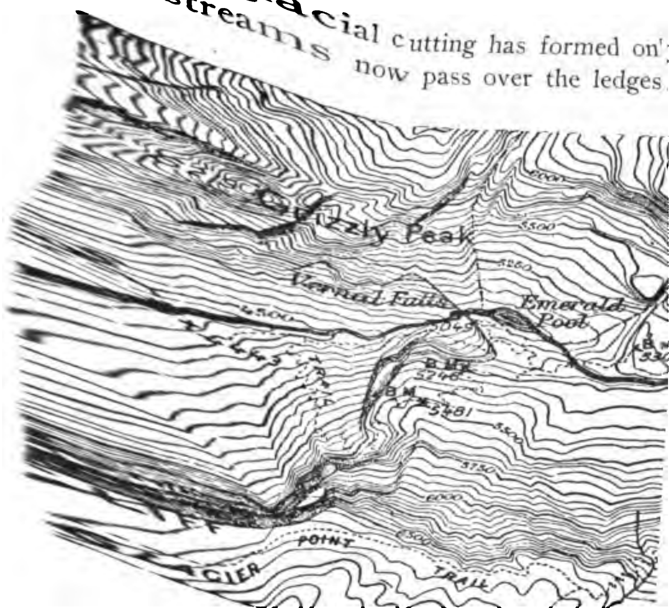

Fig. 6—Vernal Falls and Nevada Falls. Just so
to weathering along joint planes, while nort
carved by the stream. Trails pass throu

difference in volume and load of stre
would appear from the relative sizes of
time has been short as compared with
interpretation the notches afford no ev
as to the efficiency of glacial erosion.

Conclusio

The Yosemite Valley is a young g
whose walls of jointed granite are in a
and whose floor has been maturely ag
The position of the trough was deter
valley which guided the advancing glaci
was favored by the shape of the glacia
mitted different ice streams to converg

unusually vigorous Yosemite Glacier. Glacial over-deepening exceeded 2,000 feet in the Yosemite region, and produced the remarkable hanging valleys for which the region is famous. Glacial oversteepening produced the steep valley walls, and made possible the effective weathering along joint planes, to which the details of cliff sculpture are due. Many of the notches in the lips of the hanging valleys are due to the joint-controlled weathering; but some are stream carved notches, deserted by their streams because of glacial interference. Both types of notches are expectable features in the side of a glacial trough located in jointed rocks.

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